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COMPLETE SPECIFICATION

Recorded Information Detection Apparatus

We, INTERNATIONAL BUSINESS MACHINES CORPORATION, a Corporation organized and existing under the laws of the State of New York in the United States of America, of Armonk, New York 10504, United States of America (assignees of RUSSELL KEPPE BRUNNER and MARTIN ORO HALFHILL) do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to recorded information detection apparatus.

The invention provides recorded information detection apparatus of the kind in which detecting means detects information-bearing signals recorded along a track on a record medium during relative movement of the detecting means and the record medium and in which failure of the detected information signals to satisfy predetermined criteria may be corrected by variation of the position of the detecting means transversely of the track, the apparatus including positioning means capable of variably positioning the detecting means transversely of the track, and testing means capable of testing the detected information, for any transverse position of the detecting means, and of producing a signal indicating a failure of the information signals to satisfy the predetermined test criteria, the positioning means being operable on receipt of such a signal to shift the detecting means, the receipt of a succession of such signals being effective to cause the positioning means to shift the detecting means through a predetermined sequence of positions.

The invention will be described further, by way of example only, with reference to a preferred embodiment thereof as illustrated in the accompanying drawings wherein:

FIGURE 1 shows a recorded information detection apparatus in accordance with the present invention;

FIGURE 2 is an enlarged fragmentary view of a track recorded on a record medium having an imperfection; and

FIGURE 3 shows a single transducer head of the apparatus of FIGURE 1 and shows alternative paths scanned by the head.

Many data storage devices employ a storage medium having a surface upon which can be recorded a plurality of parallel tracks. Examples of such devices include magnetic tape systems, drums, disc files and strip files. These systems all employ apparatus including one or more transducers, a storage medium having a magnetisable surface, and means for causing relative movement between the transducer or transducers and the storage medium thereby to read or write strings of data on the tracks.

Referring to FIGURE 1, recorded information detection apparatus according to the invention is shown in use with a disk file 10. However, the present invention may be utilised with any of the above systems employing relative motion between a transducer and the data storage medium to read the stored data.

The basic need for the present invention will now be illustrated by reference to FIGURE 2. Those of the above systems presently in use employ a non-magnetic substrate having a thin, magnetisable material coated or plated thereon. Numerous examples appear in common usage. In the example shown, each disk of file 10 comprises an aluminum substrate 11 which is coated on either side with a ferro-magnetic powder suspended in a plas-

[Price 4s. 6d.]

tic binder 12. It is not yet economically feasible to manufacture such coatings so as to be completely free of detectable defects at the high density of presently recorded data. Hence, occasional pin holes or magnetic or non-magnetic impurities may appear in the coating material. In Figure 2, a fairly large impurity 13 is shown embedded in the coating 12. The impurity extends into one side of a track 14 recorded in the coating 12. A transducer which reads the data comprising track 14 is represented by a schematic representation of a magnetic gap 15. If the gap 15 is exactly centered with respect to track 14, or is positioned slightly to the right of the center of track 14, the different magnetic properties of impurity 13 with respect to the coating 12 may cause transducer 15 to misread the data comprising track 14. The present invention provides apparatus for automatically responding to the erroneous data generated by impurity 13 to adjust the path of transducer 15 to the left. This adjustment will, in most cases, allow the transducer 15 to correctly read the data comprising track 14.

With reference to the embodiment of the invention shown in Figure 1, the basic positioning servosystem may comprise any suitable track-following servosystem.

In the arrangement shown in Figure 1, a ganged transducer head assembly 20 includes a plurality of separate transducers 21 for the magnetic recording and reproducing of stored data, and a separate servo transducer head 22. All of the transducers are suspended from carriage 23 so as to be accurately aligned with one another and with respect to disks 24 and 25.

Referring additionally to Figure 3, each transducer 21 comprises a magnetic core 26 wound with a coil 27. The magnetic core ends in two pole pieces at the surface of a slider 28, forming a gap 15 therebetween. The slider is designed to fly at a precise distance away from the surface of the disk, supported against a biasing force by the flow of air being dragged with the moving disk surface. The slider is suspended by a flexible gimbal 29 from support arm 30. The gimbal allows the slider to pivot in any direction so that it may fly parallel to the disk surface. Each of the support arms is mounted on carriage 23 which moves the transducers radially with respect to disks 24, 25. The coil 27 for each transducer is connected by means of wires 31 and 32 to the remainder of the system, as will be described. Further details as to the specific electrical and mechanical arrangements of the transducers and positioning mechanisms are conventional, and have been omitted for the sake of clarity.

The disk file 10 comprises a central shaft 33 which supports disks 24 and 25 perpendicular to the axis thereof and axially aligned therewith. A motor (not shown) rotates shaft 33 thereby causing relative motion between the transducers 21, 22 and the disks 24 and 25.

With the carriage 23 stationary, the transducers 21, 22 each trace along a circular track on the corresponding disk surface. The tracks all lie in a common cylinder having a central axis concentric with shaft 33. Movement of carriage 23 changes the radius of the cylinder traced by the transducers 21, 22. Accurate positioning of the carriage 23 is determined from signals detected by servo transducer 22. These signals are supplied to position error detection circuitry 35. This circuitry provides as an output a position error signal indicating the direction and amplitude of the position error of the carriage. This output is supplied to a summing amplifier 36. The output of the summing amplifier is connected to a servo driver 37. The servo driver provides an output current "I" proportional to the voltage output of summing amplifier 36. Current from servo driver 37 drives a servo actuator 38. The servo actuator 38 may be of any suitable type for moving carriage 23 toward or away from shaft 33 in response to the output current from servo driver 37.

The described position error servosystem operates to cause the ganged transducers 21, 22 to accurately follow the desired servo track on the servo surface of disk 24. Hence, servo transducer 22 is maintained in alignment with the servo track. It is possible, when such disks are interchangeable between machines, that the data transducers 21 may be offset from the respective data tracks, even though the servo transducer is accurately aligned, because of tolerance differences between machines.

Data transducers 21 each detect data recorded on the corresponding surface of rotating disks 24 or 25. A specific transducer is selected by means of switching circuitry 40. The switching circuitry may comprise any suitable switching network for selectively interconnecting the output wires 31, 32 of one of the transducers 21 to line 41. Line 41 is connected to read amplifier 42, which amplifies the output of switching means 40. The amplified signal is then supplied to data separator 43. The data separator comprises circuitry for analyzing the output of read amplifier 42 and decoding those signals into binary "ZERO" or "ONE" data bits at a specified clocking rate.

The output of data separator 43 is transmitted to error detection circuitry 44, and also to storage means 45. The error detection circuitry 44 analyses the data supplied from data separator 43 to detect whether the data is erroneous. The error detection circuitry may comprise any suitable means for detecting at least one error in the data comprising

the output of data separator 43. In order that the subject error detection circuitry work properly, the data as originally encoded for recording on the disk file 10 must have been analysed and redundant data added thereto by the corresponding encoder.

Conventionally, the ultimate error detection is made by an Exclusive OR circuit. If the output of the Exclusive OR circuit is 0, no error has been detected. However, an error in the received data causes the Exclusive OR circuit to provide a "1" output. The output of this Exclusive OR circuit is supplied to the "ON" input to trigger 46. The other input to trigger 46 comprises reset input 47. A signal is supplied at reset input 47 immediately prior to completion of the error detection sequence by circuitry 44. Therefore, trigger 46 remains reset OFF until such time as an error is detected by error detection circuitry 44. So long as the trigger is OFF, a positive output is supplied on "OK" line 48. If an error is detected by error detection circuitry 44, a positive signal is supplied to the ON input of trigger 46. This input switches the trigger so that the signal on line 48 is turned OFF and a positive signal applied on "ERROR" output line 49.

Storage means 45 comprises any suitable means for storing the data received from data separator 43 for a time sufficient for error detection circuitry 44 to analyse the entire block of data and determine whether the data is correct or incorrect. Examples of such storage means comprise a serial storage register or a delay line.

After completion of the error detection sequence, the storage means 45 serially transmits the stored data to a gate circuit 50. The controlling input of the gate circuit is connected by line 48 to the "OK" output of error trigger 46. The output of gate circuit 50 comprises data output terminal 51.

Hence, if no error is detected during the error detection sequence, error trigger 46 remains OFF, supplying an output signal on line 48. The data as transmitted from storage means 45 is therefore transmitted by gate 50 to the data output terminal 51. However, should error detection circuitry 44 detect an error, a signal is provided therefrom to the ON input of error trigger 46. This turns the trigger ON, providing an output on "ERROR" output terminal 49 and turning OFF the output on line 48. Therefore, gate circuit 50 blocks the transmission of data from storage means 45.

The "ERROR" output of error trigger 46 is connected to the input of bias trigger 52 and to the controlling input of gate circuit 53. Bias trigger 52 alternatively supplies opposite polarity signals on lines 54 and 55. This means that in one condition of the bias trigger, output line 54 is positive with respect to line 55; and in the other condition, output line 55 is positive with respect to line 54. These lines are connected to a bias amplifier 56, which amplifies the net signal and supplies either a positive or negative signal on line 57, depending upon the condition of bias trigger 52. Bias trigger 52 is switched from one condition to the other by the positive going transition of an error output signal from error trigger 46. Hence, as error detection circuitry 44 detects an error in the data, it provides an output to error trigger 46. This causes the error trigger 46 to turn OFF the output of line 48 and provide an output signal on line 49. The positive going portion of this output signal causes bias trigger 52 to flip and change the polarity of its net output, which output is amplified by amplifier 56 and supplied on line 57. At the same time, the error signal from error trigger 46 operates gate 53 to thereby transmit the bias signal from line 57 to summing amplifier 36.

The biasing signal from gate 53 is, dependent upon the signal thereof, added or subtracted to the output of servo detection circuitry 35 in summing amplifier 36. Hence, the output of summing amplifier 36 is no longer dependent entirely upon the distance of servo transducer 22 from the center of the servo track, but, rather, is dependent additionally on the biasing signal from gate circuit 53.

Servo driver 37 provides an output current "I" in response to the signal received from summing amplifier 36. This current drives actuator 38 to reposition carriage 23 and, therefore, the ganged transducers 21, 22, laterally with respect to the data and servo tracks. The repositioning will continue until such time as the servo transducer 22 is driven off the center of the corresponding servo track so that the position error output of detection circuitry 35 exactly counter-balances the bias signal from gate circuit 53. At such time, the net output from summing amplifier 36 is zero and therefore the ganged transducers 21, 22 are following a path parallel to, but slightly offset from, the centre of the servo track.

In operation, ganged transducer head assembly 20 is initially positioned at a desired set of tracks on disks 24 and 25. Servo transducer 22 reads the servo information and transmits corresponding signals to detection circuitry 35. The detection circuitry analyses the received servo information, and provides a position error signal indicating the direction and distance that the head assembly must be moved to bring the servo transducer into alignment with the center of the corresponding servo track. The position error signal is transmitted by summing amplifier 36 to servo driver 37. The servo driver transmits a current "I" to actuator 38 in response to the position error signal. This current operates the

actuator 38 to position carriage 23, and hence to centre transducers 21 and 22 laterally with respect to the servo track.

Upon obtaining proper alignment, switch 40 operates to connect a desired one of the data transducers 21 to line 41. Referring additionally to Figure 3, it is assumed that, when so aligned, the magnetic gap 15 in coil 26 of the selected transducer 21 traces along a path, the center line of which is designated by line 60.

The data received from the selected transducer 21 is amplified by read amplifier 42 and supplied to data separator 43. The data separator analyses the signal so received and decodes them into "ZERO" or "ONE" data bits for transmission to error detection circuitry 44 and to storage means 45. The storage means 45 stores the data so received for the duration of an error detection sequence by the circuitry 44. The error detection circuitry analyses the data and indicates whether an error is detected thereby. If no error is detected, the output therefrom remains OFF, and error trigger 46 is maintained in a reset condition, as initially reset by input 47. As so reset, error trigger 46 supplies an output signal on "OK" line 48 to gate circuit 50. This signal maintains gate circuit 50 open so that the subsequent serial transmission by storage means 45 of the stored data is supplied by gate 50 to data output terminal 51.

However, should error detection circuitry 44 detect at least one error in the analysed data, an output signal is transmitted to error trigger 46. The signal turns ON the trigger to thereby remove the output from line 48 and, instead supply an output signal on "ERROR" line 49.

The removal of the control signal on line 48 to gate 50 causes the gate to block transmission of data from storage means 45. Hence, no data is supplied to data output 51.

At the same time, the positive-going transition of the signal on line 49 causes bias trigger 52 to flip to the opposite condition from its previous state. This changes the polarity of the output on lines 54 and 55. Assume, for example, that the resultant output from bias trigger 52 causes line 55 to be positive with respect to line 54. Therefore, bias amplifier 56 amplifies the resultant signal, which is of negative polarity, for transmission on line 57 to gate circuit 53. The output from error trigger 46 on line 49 has also operated gate 53 so that the gate transmits the bias signal from line 57 to summing amplifier 36. The negative bias signal is combined with the position error signal from detection circuitry 35 by the summing amplifier 36. The net signal is transmitted to servo driver 37 which produces a current to drive actuator 38 and thereby reposition carriage 23.

As the carriage 23 and transducers 21, 22 are repositioned, the resultant output from servo transducer 22 is altered. The alteration is due to the different relationship between the servo transducer and the center of the servo track. The repositioning by the servo driver 37 and actuator 38 continues until such time as the new output from servo transducer 22 as analysed by detection circuitry 35 produces a position error signal which exactly counter-balances the bias error signal from gate circuit 53.

When so balanced, the selected data transducer 21 scans a path 61 (shown in Figure 3) slightly offset from the center line of the previous path 60.

When so repositioned, the output of the selected data transducer 21 is again transmitted via switch 40, line 41 and read amplifier 42 to data separator 43. Again, the data is separated and transmitted to error detection circuitry 44 and to store means 45. Error detection circuitry 44 analyses the newly read data and indicates whether or not an error is detected.

If the initial bias supplied by bias trigger 52 and bias amplifier 56 to the summing amplifier 36 was of the wrong polarity, so that the data transducer is positioned further away from the correct data, the error detection circuitry 44 again transmits an error indication to error trigger 46. Again, error trigger 46, having been reset OFF, is turned ON by the error signal. Upon being turned ON, the error trigger provides an error signal on line 49 to bias trigger 52 and to gate circuit 53.

The positive-going transition of the error signal operates bias trigger 52 to switch states. Now, the output of the bias trigger on line 54 is positive with respect to the output on line 55. This signal is amplified by bias amplifier 56 and supplied on line 57 and is now positive in polarity. The error signal again operates gate 53 to transmit the positive bias signal to summing amplifier 36.

The summing amplifier 36, servo driver 37 and actuator 38 now operate to drive the carriage 23 in the opposite direction until repositioned at such a point that the new position error output from detection circuitry 35 balances the bias input to summing amplifier 36. As shown in Figure 3, the selected data transducer 21 is now positioned to trace a track centered along line 62.

When so repositioned, the output of the selected data transducer is again transmitted by switch 40, line 41 and read amplifier 42 to data separator 43. The new data is separated and supplied to error detectors 44 and a storage means 45. The error detection sequence again takes place and, since the data transducer 21 is now positioned closer to the correct data, error detection circuitry 44 may not indicate an error. If no such indication is forthcoming, error trigger 46 remains re-

set OFF so as to supply an output on line 48 to operate the gate circuit 50. In this case, at the end of the error detection sequence storage means 45 serially transmits the data to gate circuit 50, which supplies the correct data to data output terminal 51.

Assuming the situation as shown in Figure 2, the data transducer 21, as represented by the gap 15 therein, may have picked up erroneous data from the track 14 due to impurity 13. Referring additionally to Figure 1, error detection circuitry 44 would detect this error and cause gate circuit 50 to block transmission of the data to the data output terminal 51. The detection of the error would also cause application of the bias which, on a 50 percent random basis, would cause the carriage 23 and transducer 21 to be repositioned toward the outside of track 14. Hence, upon re-reading along the second path, the gap 15 of the transducer 21 would be located more directly over the impurity 13 and hence, the error would have been repeated. Again, the error would be detected and again would have prevented transmission of the data to data output terminal 51. The error detection would cause the bias trigger 52 to switch to the opposite state, thereby reversing the polarity of the bias signal. The bias signal would cause the carriage 23 and transducer 21 to be repositioned in the opposite direction by an amount approximately equal to that of the first repositioning.

The gap 15 of data transducer 21 would then be positioned over the good portion of track 14 and would read the data comprising track 14 correctly. As a result, error detection circuitry 44 would make no error indication. Hence, the error trigger would be reset OFF and the data transmitted from storage means 45 via gate 50 to the data output terminal 51.

Likewise, had the data transducer 21 been offset with respect to track 14 such that it was reading part of the data from an adjacent track, operation of the error detection means would provide a biasing signal causing repositioning of the data transducer 21. As a result of the bias, the gap 15 of the data transducer would either be positioned more directly over the desired track, or further from the centre of the desired track so as to detect more of the adjacent track. Again, the error detection circuitry 44 would determine whether or not the gap 15 was correctly positioned and, if not, cause bias trigger 52 to reverse the bias and reposition the data transducer an equal amount in the opposite direction.

As a result of the present invention, data tracks 14 may be made smaller and placed closer together without the fear of losing data permanently due to impurities 13 or due to minor misalignments between data transducers 21 on various storage devices 10 having interchangeable media. In apparatus according to the present invention, any erroneous data is, in a majority of cases, retrievable on the immediately following or the next following pass of data transducer over the desired data.

The disclosed apparatus may also be used with transducers 21 and associated writing circuitry for performing diagnostics, Specifically, an input signal may be applied at input terminals 63 to error trigger 46 to turn ON the trigger. The trigger responds by blocking gate circuit 50 to prevent transmission of any data, and provides a signal on line 49. The positive-going transition of the signal switches bias trigger 52 and the signal operates gate 53 to transmit the resultant bias signal to summing amplifier 36. As discussed previously, the bias signal causes the servo system to follow along a path 61 or 62 slightly offset from the center path 60. While so offset, the writing circuitry may cause a transducer 21 to write data on the associated disk. The input signal at terminal 63 is then removed, the error trigger reset, and then the recorded data is read back to allow error detection circuitry 44 to detect any errors. Operation in this manner may assist in locating impurities which otherwise may cause only intermittent errors to occur.

The invention is applicable to any system employing strings of data recorded on a storage mechanism and utilising any suitable transducing means for reading that data. Examples are magnetic heads for reading data recorded in tracks on a magnetic storage medium, as well as optical laser or electron-beam scanning means and associated detection apparatus for scanning along tracks of optically recorded data or magnetically recorded data subject to optical or electron-beam readout, such as by the Kerr effect.

WHAT WE CLAIM IS:—

1. Recorded information detection apparatus of the kind in which detecting means detects information-bearing signals recorded along a track on a record medium during relative movement of the detecting means and the record medium and in which failure of the detected information signals to satisfy predetermined criteria may be corrected by variation of the position of the detecting means transversely of the track, the apparatus including positioning means capable of variably positioning the detecting means transversely of the track, and testing means capable of testing the detected information, for any transverse position of the detecting means, and of producing a signal indicating a failure of the information signals to satisfy the predetermined test criteria, the positioning means being operable on receipt of such a signal to shift the detecting means, the receipt of a succession of such signals being

effective to cause the positioning means to shift the detecting means through a predetermined sequence of positions.

2. Apparatus as claimed in claim 1 including storage means for storing the detected information and in which the testing means tests the information stored in the storage means for error according to predetermined criteria.

3. Apparatus as claimed in either of claims 1 and 2 in which the record medium is magnetisable and the detecting means includes an electromagnetic transducing head.

4. Apparatus as claimed in claim 3 in which the positioning means includes a servomechanism operable to maintain the electromagnetic transducer head in a position fixed transversely of a track and further includes biasing means operable in response to a signal from the testing means to bias the servomechanism so as to alter the position fixed transversely of the track.

5. Apparatus as claimed in claim 4 wherein the electromagnetic transducer head constitutes one of a plurality of such heads, the plurality of heads being linked for movement together.

6. Apparatus as claimed in any of claims 3, 4 and 5 including at least one rotatable disc having annular tracks of magnetically recorded information bearing signals thereon and in which the positioning means are capable of positioning the electromagnetic transducer head or heads radially over the disc surface.

7. Recorded information detection apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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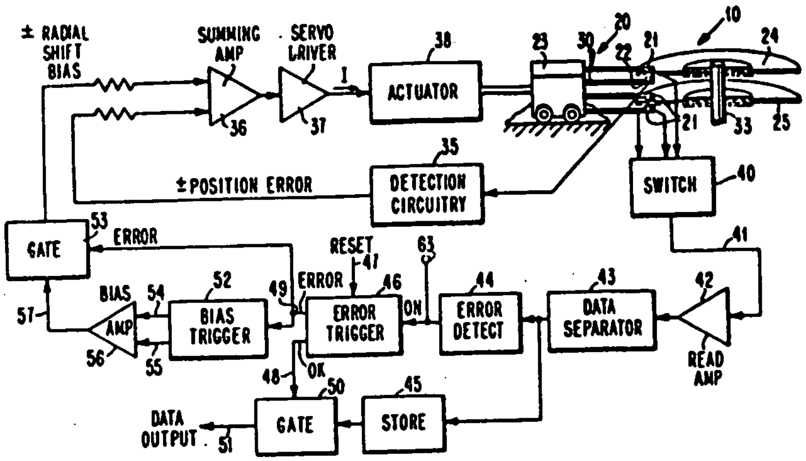

FIG.1

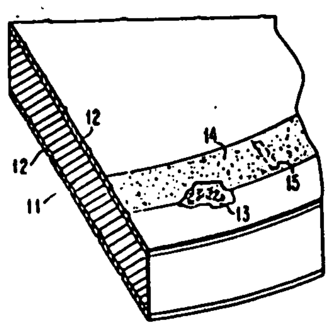

FIG.2

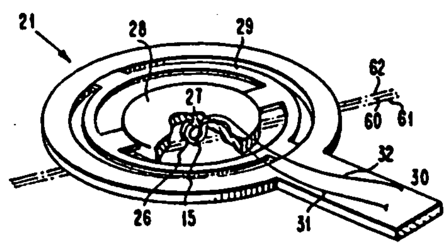

FIG.3